Arctic Climate Observations Using Underwater Sound (ACOUS)

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LONG-TERM GOAL

The long-term goal of ACOUS is to advance the understanding of short (seasonal) and long-term (annual, interannual and decadal) variability in the Arctic Ocean and its relation to global climate trends.

OBJECTIVES

The principal objective of ACOUS is to conduct a research program to monitor changes in the ocean temperature and extent of ice cover in the Arctic Ocean using underwater acoustic remote sensing.

- The first objective of this research is to measure directly Arctic Ocean temperature trends and the upper mixed layer depth using acoustic thermometry and innovative acoustic technologies.
- The second objective of this research is to measure directly changes in the Arctic Ocean ice cover thickness and extent using an acoustic intensity based tomographic method.
- The third objective of this research is to assimilate these data into Arctic Ocean-Ice-Atmosphere models, and to merge them with satellite temperature, altimeter, and SAR data acquired in other programs.
- The fourth objective is to continue the close association with the Russian former defense S&T community and assist in the survival of Russian technology infrastructure and its conversion to non-defense applications. ACOUS is an approved Gore-Chernomyrdin project since 1995.

APPROACH

Install acoustic sources and receivers in the Arctic Ocean and perform long-term monitoring of Arctic Ocean temperature trends and ice cover thickness. Assimilate the data from long-term monitoring into Arctic Ocean-Ice-Atmosphere models to improve their capability and supporting data bases for more accurate forecasts of Arctic environmental changes, which are of major impact on global change and climate prediction. Use acoustic remote sensing to advance the understanding of short and long-term variability in the Arctic Ocean.

WORK COMPLETED

The ACOUS team designed, built and tested the Acoustic Source Complex in accordance with the joint U.S.-Russian Implementation Plan. The Source Complex was installed from the Russian icebreaker, Academician Fedorov, off Franz Josef Land in September-October 1998. The source is located at approx. 81-56N, 038-44E, and is moored in 440 meters of water and suspended from the bottom to a depth of 60 meters. The source transmits at 20.49 Hertz, beginning at 0000Z every fourth day, and will operate for over two years. The operational power output level of the source is 195 dB with a

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guaranteed lifetime of 2 x 10^8 cycles. The source transmits a Maximum Likelihood Signal (MLS) M-sequence, M255, for 10 periods that equals 1275 seconds (21.25 minutes).

An autonomous acoustic receive array was designed, constructed and installed in the Lincoln Sea in September-October 1998. The array is located at approx. 84-03.406N, 066-24.924W near the existing Spinnaker Array, and is moored in 545 meters of water. The array is 518 meters long and contains 8 hydrophones spaced 70 meters apart. The system records a 4-hertz bandwidth about 20 Hertz. The system started recording at 2310Z on 2 October 1998, and records for 2 hours every 4 days. It will record the signal from the Russian ACOUS Acoustic Source for about eighteen months, and will then be recovered to retrieve the data. The array has five CTDs that record at 10-minute intervals. There are three transponders deployed on the bottom symmetrically around the array at a distance of about 500 meters. Two transceivers are mounted on the array to provide array element location reconstruction. The transceivers sample the transponders for 4 hours every 4 days centered on the acoustic source transmissions. A schematic of the acoustic receive array is attached.

We attempted the repair of the Spinnaker Receive Array in the Lincoln Sea in April-May 1998. This array would have provided continuous real-time data. Four breaks in the fiber optic trunk cable were repaired. There was insufficient time available to complete the repair of the fifth and final break in the cable.

The cabled acoustic receive array planned for installation in the Beaufort Sea off Pt. Barrow, Alaska, has been designed and fabrication has begun.

An ATOC receive system installed at a Russian acoustic station in Kamchatka in the fall of 1996 was operated in March 1998. Data was acquired from this station from the ATOC/North Pacific Acoustic Laboratory (NPAL) acoustic source located off Kauai to expand the proposed coverage of the NPAL. The plan is to activate this receiver for continuous operations over a three-year period starting in 1999.

An Environmental Compliance Analyses was completed for the possible impact of the ACOUS Russian Acoustic Source on marine mammals. The final briefing to NMFS and the Marine Mammal Commission was completed in July 1998. The analyses was approved by the Office of Naval Research (ONR), National Marine Fisheries Service (NMFS), and OPNAV (N44).

Two meetings of the joint U.S.-Russian Coordinating Committee Working Group were conducted in October 1997 and July 1998. The joint U.S.-Russian Implementation Plan for the FY-98 Program was completed and implemented.

Five publications and four technical reports were completed, and one invited paper was presented.

The following presentations were made:

Gavrilov, A.N., and P.N. Mikhalevsky, “Acoustic Thermometry in a Range-Dependent Ocean,” Proceedings of the Fourth European Conference on Underwater Acoustics, Rome, Italy, September 1988.

Mikhalevsky, P.N., “Arctic Climate Observations using Underwater Sound (ACOUS),” U.S. Arctic Research Commission, Smithsonian Institution, Washington, DC, February 24, 1998.

Mikhalevsky, P.N., "ACOUS Status Report," to Dr. Jack Gibbons, (President's Science Advisor), Dr. Neal Lane (Director NSF), and Acad. V.E. Fortov (Russian Minister of Science), GCC-10 Meeting, U.S. Department of State, Washington, DC, March 6, 1998.

Mikhalevsky, P.N., "SCICEX and Acoustic Monitoring in the Arctic," NSF/ONR SCICEX 2000 Workshop, Airlie Conference Center, Virginia, October 6-8, 1998.

The following technical reports were completed:

Bogolyubov, B.N., "Design, Manufacture and Testing of a Prototype Arctic Acoustic Source Complex, Stage 1, Preliminary Technical Report 2," Nizhny Novgorod, Russia, 1998.

Bogolyubov, B.N., "Emitter Complex Design, Acoustic Source Construction and Plant Testing, Stage 1, Preliminary Technical Report 3," Nizhny Novgorod, Russia, 1998.

Karlik, J.S., et al, "Activate ATOC Signal Receiving Equipment in Kamchatka, Technical Report, Stage 1," Nizhny Novgorod, Russia, 1998.

Lents, J.M., "ACOUS Lincoln Sea Deployment Overview," Science Applications International Corporation (SAIC), McLean, VA, 15 October 1998.

RESULTS

- Analysis of TAP data was completed and this analysis supported the design of the maximal length sequences (MLS) signals currently being transmitted by the ACOUS source in the Arctic, and confirmed that travel time change resolution of 0.5 msec is achievable.
- Analysis of CTD data from the SCICEX program, and the modeling work of Prof. Mark Johnson, UAF, show that the ACOUS MLS signals will easily resolve expected seasonal, annual and interannual trends in Arctic Ocean temperature.
- Acoustic modeling of mixed layer depth measurement, and sea ice thickness and roughness measurements using new methods of acoustic remote sensing are very promising and will continue to be explored.
- Analysis of the ATOC signals transmitted from Kauai and received in Kamchatka revealed several stable arrivals suitable for long-term tracking. Some of the transmissions exhibited low SNR most likely due to shipping in close proximity to the receive array.

IMPACT/APPLICATION

The ACOUS Project will provide data to enhance Arctic Ocean circulation models to improve the capability to forecast significant global environmental events. The improvement of under ice acoustic propagation modeling, development of new low-frequency acoustic source technology, and the access to Russian Arctic data bases under data sharing protocols already approved, have important payoffs. High level positive visibility in assisting Russian defense R&D to transition to non-defense applications, is another important payoff.

RELATED PROJECTS

1 – The North Pacific Acoustic Laboratory (NPAL) is acquiring data from the ATOC receive system installed at a Russian acoustic station in Kamchatka. The ATOC receive system was activated with support from the ACOUS Project.

2 - The SCICEX (Scientific Ice Expeditions) Project of US submarine Arctic cruises has obtained measurements along the propagation tracks that will be used by the ACOUS Project. The SCICEX data has allowed the assessment of hypothesized circulation changes, and will provide ground-truth for accurate modeling and understanding of the first acoustic measurements, as well as, an independent observation of changes that could be compared with the acoustic results.

3 - A major study of Arctic change is being formulated by Dr. Jamie Morison, Polar Science Center, APL/UW. The effort started at an open workshop at the University of Washington in November 1997, which was supported by the Arctic Systems Science (ARCSS) Program of the National Science Foundation Office of Polar Programs. The ACOUS Project was represented at the workshop and was endorsed as one of the observational techniques needed as part of an overall Arctic monitoring strategy.

PUBLICATIONS

Gavrilov, A.N., and P.N. Mikhalevsky, "Mode coupling effects in acoustic thermometry of the Arctic Ocean," J. Acoust. Soc. Am., submitted December 1997.

Gavrilov, A.N., "On the Experiment, Arctic Climate Observation Using Underwater Sound (ACOUS)," Ocean Acoustics, Short Collection of the Works of the School Seminar Academician, L.M. Brekhovskikh (in Russian), 1998.

Johnson, M.A., A.Y. Proshutinsky, and I. Polyakov, "A coupled ocean-atmosphere Arctic Oscillation," submitted 1998, Geophys. Res. Letters.

Mikhalevsky, P.N., A. Gavrilov, and A.B. Baggeroer, "Transarctic acoustic propagation experiment and climate modeling in the Arctic," IEEE, J. Oceanic Engineering, invited paper accepted October 1998.

Sabinin, K.D., Sokolov, V.T., "Acoustic Monitoring of the Arctic Ocean: Key Regions and Objects," Ocean Acoustics, Short Collection of the Works of the School Seminar Academician, L.M. Brekhovskikh (in Russian), 1998.

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